Estuarine Landcover Along the Lower Columbia River Estuary Determined from Compact Airborne Spectrographic Imager (CASI) Imagery

Technical Report
2003

DOE/BP-00008768-2

October 2003

This Document should be cited as follows:

Garono, Ralph, Rob Robinson, Charles Simenstad, "Estuarine Landcover Along the Lower Columbia River Estuary Determined from Compact Airborne Spectrographic Imager (CASI) Imagery", Project No. 2002-01200, 63 electronic pages, (BPA Report DOE/BP-00008768-2)

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

Estuarine Landcover Along the Lower Columbia River Estuary Determined from Compact Airborne Spectrographic Imager (CASI) Imagery

October 2003

Submitted to

Bonneville Power Administration
US Army Corps of Engineers
Lower Columbia River Estuary Partnership

by

Ralph J. Garono & Rob Robinson

Wetland & Watershed Assessment Group, Earth Design Consultants, Inc.

in cooperation with

Charles Simenstad

Wetland Ecosystem Team,
School of Aquatic and Fishery Sciences, University of Washington

Wetland & Watershed Assessment Group
Earth Design Consultants, Inc.
230 SW Third, Suite 212
Corvallis, OR 97333
541.757.7896
http://www.earthdesign.com

Table of Contents

Introduction

Developing an understanding of the distribution and changes in estuarine and riparian habitats is critical to the management of biological resources in the lower Columbia River. In a recently completed comprehensive ecosystem protection and enhancement plan for the lower Columbia River Estuary (CRE), Jerrick (1999) identified habitat loss and modification as one of the key threats to the integrity of the CRE ecosystem. This management plan called for an inventory of habitats as key first step in the CRE long-term restoration effort. While previous studies have produced useful data sets depicting habitat cover types along portions of the lower CRE (Thomas, 1980; Thomas, 1983; Graves *et al.*, 1995; NOAA, 1997; Allen, 1999), no single study has produced a description of the habitats for the entire CRE. Moreover, the previous studies differed in data sources and methodologies making it difficult to merge data or to make temporal comparisons. Therefore, the Lower Columbia River Estuary Partnership (Estuary Partnership) initiated a habitat cover mapping project in 2000. The goal of this project was to produce a data set depicting the current habitat cover types along the lower Columbia River, from its mouth to the Bonneville Dam, a distance of ~230-km (Fig. 1) using both established and emerging remote sensing techniques.

For this project, we acquired two types of imagery, Landsat 7 ETM+ and Compact Airborne Spectrographic Imager (CASI). Landsat and CASI imagery

differ in spatial and spectral resolution: the Landsat 7 ETM+ sensor collects reflectance data in seven spectral bands with a spatial resolution of 30-m and the CASI sensor collects reflectance data in 19 bands (in our study) with a spatial resolution of 1.5-m. We classified both sets of imagery and produced a spatially linked, hierarchical habitat data set for the entire CRE and its floodplain. Landsat 7 ETM+ classification results are presented in a separate report (Garono *et al.*, 2003). This report presents classification results from analysis of the CASI imagery. Data sets produced for this project from both types of imagery fill a critical information gap by creating a current description of the condition and extent of estuarine habitat cover types along the lower Columbia River.

Results from this study will be used by the Estuary Partnership and its cooperators to: (1) develop indicators of "habitat health" and biological integrity; (2) develop definitions of "critical salmonid habitat"; (3) identify and evaluate potential wetland conservation and restoration sites; (4) track exotic and invasive species; and (5) develop an understanding of how estuarine and riverine habitats have changed over the past 200 years. This study focuses on estuarine and riparian habitat cover types important to native species, particularly juvenile salmonids. This study is meant to provide support to the multiple efforts currently underway to recover 12 species of Columbia River

salmonids identified as endangered or threatened under the Endangered Species Act.

Methods

We collected 19-band CASI imagery from 136 flightlines of varying length for several key areas (Fig. 1), focal areas (FA), in the CRE during 30-31 July and 1-2 August 2000 and during 19-23 August 2001. The CASI sensor, operated by Hyperspectral Data International, Inc. (HDI), was mounted in a factory installed camera port on a DeHavilland Beaver, operated by Ecotrust. The aircraft was flown at an altitude of 1,140-m AGL at approximately 176-183-km hr^{-1}. This resulted in a pixel size of 1.5-m and a ground track of approximately 768-m. CASI is a push broom type sensor that builds the image of each flightline one scan line at a time. One of the primary limitations of a push broom type sensor is that it can be difficult to geocorrect the imagery. The cause of this limitation is that distortion added to the imagery by the movement of the aircraft (pitch, yaw and roll) must be removed. Initially, HDI removed image distortion due to the aircraft attitude and geocorrected CASI flightlines to +/-50-100-m using filtered attitude data. Effects of downwelling light were also removed from the CASI data by HDI using measurements from the onboard incident light sensor. Weather, logistics and expense kept us from collecting CASI data for the entire study area. However, we collected CASI data for 34,400-ha the study area (~26% of the area covered in the classified Landsat 7 ETM+ imagery).

The advantages that CASI sensor has over the Landsat 7 ETM+ sensor are its increased spectral and spatial resolution. Greater spatial resolution means that smaller estuarine features (e.g., tidal channels, small vegetation patches, etc.) are visible in the CASI imagery compared to the Landsat 7 ETM+ imagery. For example, features approximately 4 X 4-m can be identified in the CASI imagery compared to a minimum of 60 X 60-m in the Landsat 7 ETM+ imagery (Fig. 2). In addition, the higher spectral resolution of the CASI sensor allowed us to better resolve spectrally similar features using the 19-band CASI imagery than with the Landsat 7 ETM+ imagery. For example, where the Landsat 7 ETM+ sensor 'sees' Herbaceous Wetland, the CASI imagery resolved several Herbaceous Wetland cover classes (e.g., sedges, rushes, purple loosestrife, etc.) that differ in dominant vegetation (Fig. 2 and Appendix A). Generally, CASI was set to record spectral bands 10-nm wide except for two bands: band 1 was set to a width of 30-nm and band 19 was set to a width of 20-nm. Wider bands at the instrument's limits of detection increased its sensitivity in these regions of the electromagnetic spectrum. We selected the CASI band sets using information collected with a hand-held radiometer (Photo Research, Inc., PR-650) and information furnished by HDI. A comparison of the spatial and spectral resolution of the Landsat 7 ETM+ and CASI sensors is shown in Table 1.

Geocorrection and Elevation Mask

Field teams established ground control points (GCPs) within each of the four FA of the larger study area. The four FA, Chinook, Russian Island, Fisher/Lord Islands, and Scappoose, are shown in Figure 1. GCPs consisted of 3 X 3-m Tyvek® tarps that were visible in the airborne imagery and could thus be used to geocorrect the imagery (Fig. 3). Positions of each GCP tarp were recorded with real-time, differentially corrected GPS units (e.g., Trimble Pathfinder ProXR). In addition to ground targets, we also used digital orthoquads to geocorrect CASI imagery. Images were reprojected to the Estuary Partnership's projection (Lambert Conformal Conic, 1st Std Parallel - 43:00:00 N, 2nd Std Parallel - 45:30:00 N, Central Meridian - 120:30:00 W, Latitude of Origin - 41:45:00 N, False Easting - 400000 meters, GRS1980, NAD83, and Coordinates in meters (not feet)).

Training Sites

To classify the imagery, we used information collected from a variety of sources including: measurements and observations by field teams; and aerial reconnaissance (a series of helicopter flights made in January and July 2002); other imagery and photography (i.e., digital orthoquads, color infrared photographs, and aerial videography). Video imagery was collected during the CASI flights over a portion of the study area. The handheld camera captured images from most other areas.

Training sites were identified in the videotapes and to some extent available digital orthoquads (DOQs) and transferred to a GIS coverage. Trained volunteers collected detailed information on the ground by setting up a 6 X 6-m grid which was precisely located using a real-time differentially corrected global positioning system (GPS). Grids were haphazardly placed in areas containing relatively homogenous plant communities. Most grids were placed between 10-50-m from GCP's (Fig. 3). Since GCP targets were visible in the CASI imagery, we were relatively certain of placement of the training sites within each image. Each ground target area was extracted from the CASI imagery and training sites, with their corresponding GCPs, were aligned exactly to the ground target visible in the imagery in order to avoid displacement due to the residual error in geocorrection. From each grid, five cells (1.5 X 1.5-m) were randomly selected and the percent cover of each plant species was recorded (to 5% cover). Digital photographs were also taken for subsequent analysis. Cover data and photographs from each grid were compared and summarized by the University of Washington's Wetland Ecosystem Team (WET). Using photo-editing software, WET personnel superimposed a 100-point grid on each ground photograph and then tallied the points intersecting each plant species. Summarized data were returned to EDC and a habitat cover class assigned to each training site. In all, we compiled and used data from 59 training sites in the classification of the

CASI imagery. Additional training sites were derived from ancillary data sources as previously described.

Classification

Following geocorrection, CASI flightlines were evaluated, prioritized for processing and mosaicked. We selected 35 flightlines in four FA (Chinook, Russian Island, Fisher/Lord Islands, and Scappoose) for classification (Table 2). Due to the greater spatial and spectral resolution of the CASI data, we identified many more cover subclasses (see 'Subclass3' in Appendix A) through analysis of the CASI data than for the habitat cover classes mapped from the Landsat 7 ETM+ imagery (see 'Subclass2' in Appendix A). To use the classified Landsat 7 ETM+ and CASI data together, we 'nested' CASI cover subclasses within the Landsat 7 ETM+ major cover classes to develop a hierarchical data set (Fig. 2). The major habitat cover classes (developed from the Landsat 7 ETM+ imagery) included: (1) Herbaceous Wetland-Tidal, (2) Herbaceous Wetland-Diked; (3) Herbaceous Wetland-Non-Tidal; (4) Herbaceous Upland; (5) Shrub-Scrub Wetland- Tidal; (6) Shrub-Scrub Wetland- Diked; (7) Shrub-Scrub Wetland- Non-Tidal; (8) Shrub-Scrub Wetland- Upland; (9) Mud; (10) Sand; (11) Deciduous Forest Wetland-Tidal; (12) Deciduous Forest Wetland-Diked; (13) Deciduous Forest Wetland-Non-Tidal; (14) Deciduous Forest Wetland-Upland; (15) Coniferous Forest Wetland-Tidal; (16) Coniferous Forest Wetland-Diked; (17) Coniferous Forest Wetland-Non-Tidal; (18) Coniferous Forest Wetland-Upland;

(19) Water; (20) Urban; and (21) Other (log rafts, etc.). These habitat cover classes were developed during a series of Estuary Partnership workshops and focusing on estuarine and riparian habitats.

Major habitat cover classes were further divided during the CASI classification (Appendix B). However, the classification accuracy assessment was conducted only for major habitat cover classes because of the limited availability of ground truth data. Because we

Table 1. Spatial and spectral characteristics of the imagery used in this project.

[A] Pixel size is determined by the altitude and speed of the aircraft. [B] The band set is programmable for the CASI sensor and was selected specifically for this project.

Sensor	Pixel Size (m)	No. Bands	Spectral Range (nm)
Landsat 7 ETM+	30	7	1) 450-515
			2) 525-605
			3) 630-690
			4) 750-900
			5) 1550-1750
			6) 10400-12500
			7) 2090-2350
Landsat 7 Pan	30	1	1) 520-900
CASI	1.5[A]	19[B]	1) 460-490
			2) 520-530
			3) 530-540
			4) 540-550
			5) 550-560
			6) 560-570
			7) 620-630
			8) 630-640
			9) 640-650
			10) 650-660
			11) 690-700
			12) 700-710
			13) 420-730
			14) 730-740
			15) 755-765
			16) 765-775
			17) 775-785
			18) 785-795
			19) 800-820

did not have representative training sites for all cover classes from all FA, we recommend that the cover subclasses (Subclass3) only be used within individual FA and not between FA. However, we did collect enough training site information for the purple loosestrife subclasses (No. 36 and 39) from multiple FA; therefore, subclasses 36 and 39 can be used to summarize purple loosestrife cover for all FA. Detailed habitat cover types are given for each FA in Appendix A.

We classified the CASI flightlines using ERDAS Imagine (Ver. 8.5). Rather than classifying each individual flightline, classification was performed on mosaics of flightlines. When flightlines were originally collected, the aircraft flew in a square pattern so that imagery was collected on ascending or descending sides of the square (in our case, either the N to S or S to N, or W to E or E to W). We did this to minimize the variability in lighting and maximize the amount of ground that could be imaged. Mosaics were constructed in ERDAS Imagine. In most cases, there were two, multi-flightline mosaics from each FA.

We used the ISODATA procedure in ERDAS Imagine to separate 100 spectral classes in the 19-band CASI image. ISODATA is an iterative, unsupervised classification algorithm. The pixels of these 100 spectral classes were then assigned to 6-7 major habitat types (largely identified from the Landsat 7 ETM+ classification). The pixels from those major habitat types were then cut from the original 19-band CASI mosaic, resulting in 6-7 individual 19-

band images. Each image subset was then run through the ISODATA classification to produce 100 (or fewer) spectral classes within these major habitat types. By dividing the image into these major habitat types, we reduced the broad spectral differences of the original full mosaic to give a much greater definition in the spectral classes after the second ISODATA. We repeated this process for pixels which did not separate between habitat class types. The pixels that had separated well into habitat classes were saved and assigned to the appropriate habitat class. Problem pixels were cut from the original 19-band image and run through ISODATA once again. We repeated this process until spectral classes for these pixels were reduced to fit into habitat classes.

Results

We collected and geocorrected 136, 19-band CASI flightlines covering 34,407.0-ha (unmosaicked total) of the Columbia River estuary. We were able to dramatically improve on the initial geocorrection using the GCP targets placed in the field by volunteers and DOQs. In all, 53 of the 145 flightlines were considered for the initial classification. In general, geocorrection of these 53 flightlines was good (average RMSE= 8.4-m: Table 2).

CASI imagery classified for the four FA covered a total of 7,070.3-ha (areas for individual FA not including the water class were Chinook=2,218.5-ha, Russian Island= 2,390.9-ha, Fisher/Lord Island=431.1-ha, and Scappoose=2,029.8-ha). Classified CASI imagery from these four FA accounts for 5.3% of the classified

Landsat 7 ETM+ imagery (excluding the water class). Twenty-one major cover classes were derived from the CASI imagery. These classes are identical to the classes derived from the Landsat 7 ETM+ imagery except for the mixed forest cover classes, which are absent from the CASI classification. We found that the high spatial resolution of the CASI imagery (i.e., 1.5-m pixels) showed individual trees. Thus, the spectral mixing we observed from coniferous and deciduous forests occurring in the 30-m Landsat 7 ETM+ pixels did not occur in the CASI imagery. An additional 85 habitat cover classes were derived from the CASI imagery using training data from field, photographic sources and ancillary data (Appendix B). The classification scheme was designed so that the detailed 85 CASI cover classes were nested within the 21 Major habitat cover classes (Fig. 2). Since not all cover classes are found in all four FA, comparisons of habitat cover types should be confined only to individual FA.

We separated tidal from diked and non-tidal areas using a 'mask.' This mask was produced using National Wetland Inventory (NWI) maps, Digital Elevation Models (DEM), Drainage District maps, DOQs, and local knowledge.

Classification Accuracy

We performed a classification accuracy assessment on each FA separately. A 3 X 3 pixel majority filter was applied to the classified imagery to remove 'salt and pepper' prior to performing the classification accuracy assessment. Application of such a filter generally increases map accuracy.

For each FA, we developed a set of accuracy assessment sites from the airborne videos. ERDAS Imagine was used to randomly select areas from the CASI imagery. The number of randomly selected sites was proportional to the area of each habitat cover class such that cover classes occupying greater areas had more assessment sites than cover classes occupying less area.

We found that the overall classification accuracy was 81.8% for the Chinook, 84.3% for the Russian Island, 91.6% for the Fisher-Lord Island, and 90.0% for the Scappoose FA. Detailed Producers and Users classification accuracy assessment results are given in Tables 3 a-d.

Previous Studies

Several previous studies have mapped habitats along the lower Columbia River. They differed in geographic extent, habitat cover classes, and approaches. All of these studies, however, used remotely sensed data in one way or another.

Thomas (1983) compared the geographic extent of five estuarine and two non-estuarine habitat types, mapped on a series of 1870 Coast and Geodetic Survey navigational charts, with results of a modern habitat mapping project. He interpreted and transferred information from historic navigational charts and modern maps to common 1:24,000 scale maps. Change in habitat types along the lower Columbia River estuary (an area from the mouth to just east of Puget Island) were then measured with a planimeter from the 1:24,000

maps. Thomas found that there was a 24% loss of area of the lower estuary. Losses occurred in the area of 'tidal swamps' (-77%), 'swamps and marshes' (-65%), and 'deep and medium depth water' (-16%) habitats and there was an increase in the area of 'shallow and flats' (+10%) habitats. This study was extended from Puget Island to the Bonneville Dam by Graves *et. al* (1995). Data sets (Thomas' 1980 maps and those produced by Graves *et al*.) are available.

Allen (1999) developed GIS layers from aerial photographs taken along the lower Columbia River in 1948, 1961, 1973, 1983 and 1991. He mapped 18 habitat cover classes (7 upland, 11 wetland) within a 3-km corridor (whenever possible) from the mouth to the Bonneville Dam. By comparing this temporal sequence of photos, he was able to measure change in habitat types. He found that during the period of 1948 to 1991, there was a 25% decrease in the area of estuarine wetlands, a 1% increase in the area of riverine tidal wetlands and a 37% decrease in riverine lower perennial wetlands for his study area.

Habitat cover types derived in previous studies differ from each other and from those derived from the YR2000 Landsat 7 ETM+ classification in this study. In addition, each study differed in geographic extent. Before study results can be compared, classification schemes must be cross-walked and the geographic extent standardized.

Table. 2. Spatial error (m) associated with each flightline. Shown are the number of Ground Control Points (GCP) used to geocorrect each flightline, the X and Y, and total Root Mean Square Error (RMSE). Smaller numbers indicate less spatial error.

Chinook

Flightline	# of GCPs	RMSE X	RMSE Y	RMSE Total
chi9*	9	4.2	6.7	7.9
chi10*	16	8.8	11.6	14.5
chi11*	17	6.5	5.0	8.2
chi12*	19	10.0	9.0	13.4
chi13*	14	2.8	3.6	4.5
chi14*	19	3.9	6.1	7.2
chi15*	18	7.8	6.9	10.4

Airport

Flightline	# of GCPs	RMSE X	RMSE Y	RMSE Total
air1	11	2.4	3.0	3.9
air2	13	5.6	6.9	8.8
air3	16	5.4	4.5	7.0
air4	12	2.9	1.3	3.1
air5b	13	2.6	0.8	2.7
air9	10	3.7	2.3	4.3
air10	8	4.5	4.0	6.0
air11	10	3.5	2.7	4.4

Fisher and Lord Islands

Flightline	# of GCPs	RMSE X	RMSE Y	RMSE Total
fli1*	8	3.3	5.2	6.2
fli2*	12	5.5	2.9	6.2
fli3*	9	13.3	4.9	14.2
fli4*	7	13.5	8.0	15.7
fli5*	11	8.5	3.9	9.4
fli6*	11	5.8	2.1	6.2
fli8*	7	3.7	2.6	4.5
fli9*	9	17.6	5.9	18.6
fli10*	9	11.6	5.4	12.8
fli11*	9	17.4	8.2	19.2
fli12*	8	2.5	4.8	5.4
fli13*	10	16.2	6.2	17.4
fli14	8	4.2	4.2	6.0
fli15	8	2.5	6.7	7.1

Russian Island

Flightline	# of GCPs	RMSE X	RMSE Y	RMSE Total
p3r01n*		8.5	5.5	10.1
p3r03n*		4.5	3.2	5.5
p3r06n*		12.9	9.5	16.0
p3r08n*		4.4	4.2	6.1
p3r02s*		5.3	5.5	7.6
p3r04s*		7.4	3.5	8.2

Scappoose

Flightline	# of GCPs	RMSE X	RMSE Y	RMSE Total
sca3*	13	3.4	4.5	5.7
sca4*	10	5.8	8.7	10.4
sca5*	16	6.1	7.6	9.7
sca6a*	18	5.1	8.3	9.8
sca7*	10	3.7	3.4	5.0
sca8*	14	7.6	9.6	12.3
sca9*	9	4.8	3.6	6.0
sca10*	13	4.0	4.4	5.9
sca11*	10	4.4	5.4	6.9
sca12*	12	13.5	5.1	14.5

Tenasilahee Island

Flightline	# of GCPs	RMSE X	RMSE Y	RMSE Total
r11	14	6.0	7.5	9.6
r13	20	4.0	4.0	5.7
r21	20	4.6	4.8	6.6
r23	17	5.4	5.9	8.0

Wallace Island

Flightline	# of GCPs	RMSE X	RMSE Y	RMSE Total
wal1	6	5.5	1.9	5.8
wal2	6	2.1	3.0	3.6
wal3	9	6.3	1.0	6.4
wal4	16	3.4	2.7	4.3

* INDICATES FLIGHTLINE WAS PROCESSED

Table 3 a. Chinook: Classification Accuracy Assessment

Habitat Cover Class	No. Training Sites	No. Classified	Number Correct	Producers Accuracy	Users Accuracy
Herbaceous Wetland-Tidal	7	7	7	100.0%	100.0%
Herbaceous Wetland-Diked	22	21	18	81.8%	85.7%
Herbaceous Wetland-Non-Tidal	5	5	5	100.0%	100.0%
Herbaceous Upland	7	6	6	85.7%	100.0%
Shrub-Scrub Wetland-Tidal	6	4	4	66.7%	100.0%
Shrub-Scrub Wetland-Diked	8	6	4	50.0%	66.7%
Shrub-Scrub Wetland-Non-Tidal	8	6	4	50.0%	66.7%
Shrub-Scrub Upland	10	9	7	70.0%	77.8%
Mud	4	4	4	100.0%	100.0%
Sand	1	0	0	---	---
Deciduous Forest Wetland-Tidal	1	3	1	100.0%	33.3%
Deciduous Forest Wetland-Diked	3	5	3	100.0%	60.0%
Deciduous Forest Wetland-Non-Tidal	4	3	3	75.0%	100.0%
Deciduous Forest Upland	5	6	2	40.0%	33.3%
Coniferous Forest Wetland-Tidal	6	6	5	83.3%	83.3%
Coniferous Forest Wetland-Diked	1	3	1	100.0%	33.3%
Coniferous Forest Wetland-Non-Tidal	4	8	4	100.0%	50.0%
Coniferous Forest Wetland-Upland	17	17	17	100.0%	100.0%
Water	4	4	4	100.0%	100.0%
Urban	7	7	7	100.0%	100.0%
Other	2	2	2	100.0%	100.0%
Totals	132	132	108		

Overall Classification Accuracy = 81.82%

Table 3 b. Russian Island: Classification Accuracy Assessment

Habitat Cover Class	No. Training Sites	No. Classified	Number Correct	Producers Accuracy	Users Accuracy
Herbaceous Wetland-Tidal	27	27	27	100.0%	100.0%
Herbaceous Wetland-Diked	17	13	13	76.5%	100.0%
Herbaceous Wetland-Non-Tidal	7	6	6	85.7%	100.0%
Herbaceous Upland	9	8	7	77.8%	87.5%
Shrub-Scrub Wetland-Tidal	8	6	6	75.0%	100.0%
Shrub-Scrub Wetland-Diked	3	4	3	100.0%	75.0%
Shrub-Scrub Wetland-Non-Tidal	3	1	0	0.0%	0.0%
Shrub-Scrub Upland	9	7	5	55.6%	71.4%
Mud	26	28	25	96.2%	89.3%
Sand	14	11	11	78.6%	100.0%
Deciduous Forest Wetland-Tidal	7	7	6	85.7%	85.7%
Deciduous Forest Wetland-Diked	3	5	3	100.0%	60.0%
Deciduous Forest Wetland-Non-Tidal	2	5	2	100.0%	40.0%
Deciduous Forest Upland	10	13	7	70.0%	53.9%
Coniferous Forest Wetland-Tidal	6	8	6	100.0%	75.0%
Coniferous Forest Wetland-Diked	4	5	4	100.0%	80.0%
Coniferous Forest Wetland-Non-Tidal	5	5	5	100.0%	100.0%
Coniferous Forest Wetland-Upland	15	15	11	73.3%	73.3%
Water	5	5	5	100.0%	100.0%
Urban	4	6	4	100.0%	66.7%
Other	1	0	0	---	---
Totals	185	185	156		

Overall Classification Accuracy = 84.32%

Table 3 c. Fisher-Lord Islands: Classification Accuracy Assessment

Habitat Cover Class	No. Training Sites	No. Classified	Number Correct	Producers Accuracy	Users Accuracy
Herbaceous Wetland-Tidal	31	30	29	93.6%	96.7%
Herbaceous Wetland-Diked	0	0	0	---	---
Herbaceous Wetland-Non-Tidal	0	0	0	---	---
Herbaceous Upland	18	18	18	100.0%	100.0%
Shrub-Scrub Wetland-Tidal	17	16	13	76.5%	81.3%
Shrub-Scrub Wetland-Diked	0	0	0	---	---
Shrub-Scrub Wetland-Non-Tidal	0	0	0	---	---
Shrub-Scrub Upland	4	8	4	100.0%	50.0%
Mud	7	6	5	71.4%	83.3%
Sand	16	19	16	100.0%	84.2%
Deciduous Forest Wetland-Tidal	58	60	57	98.3%	95.0%
Deciduous Forest Wetland-Diked	0	0	0	---	---
Deciduous Forest Wetland-Non-Tidal	0	0	0	---	---
Deciduous Forest Upland	21	17	17	81.0%	100.0%
Coniferous Forest Wetland-Tidal	1	0	0	---	---
Coniferous Forest Wetland-Diked	0	0	0	---	---
Coniferous Forest Wetland-Non-Tidal	0	0	0	---	---
Coniferous Forest Wetland-Upland	0	0	0	---	---
Water	6	5	5	83.3%	100.0%
Urban	0	0	0	---	---
Other	0	0	0	---	---
Totals	179	179	164		

Overall Classification Accuracy = 91.62%

Table 3 d. Scappoose: Classification Accuracy Assessment

Habitat Cover Class	No. Training Sites	No. Classified	Number Correct	Producers Accuracy	Users Accuracy
Herbaceous Wetland-Tidal	14	14	13	92.9%	92.9%
Herbaceous Wetland-Diked	21	19	19	90.5%	100.0%
Herbaceous Wetland-Non-Tidal	4	4	4	100.0%	100.0%
Herbaceous Upland	10	10	10	100.0%	100.0%
Shrub-Scrub Wetland-Tidal	6	6	5	83.3%	83.3%
Shrub-Scrub Wetland-Diked	0	1	0	---	---
Shrub-Scrub Wetland-Non-Tidal	7	5	5	71.4%	100.0%
Shrub-Scrub Upland	5	5	5	100.0%	100.0%
Mud	6	6	6	100.0%	100.0%
Sand	4	4	4	100.0%	100.0%
Deciduous Forest Wetland-Tidal	20	18	18	90.0%	100.0%
Deciduous Forest Wetland-Diked	6	3	3	50.0%	100.0%
Deciduous Forest Wetland-Non-Tidal	4	3	3	75.0%	100.0%
Deciduous Forest Upland	17	16	15	88.2%	93.8%
Coniferous Forest Wetland-Tidal	4	6	4	100.0%	66.7%
Coniferous Forest Wetland-Diked	0	4	0	---	---
Coniferous Forest Wetland-Non-Tidal	1	4	1	100.0%	25.0%
Coniferous Forest Wetland-Upland	5	7	5	100.0%	71.4%
Water	5	5	5	100.0%	100.0%
Urban	5	5	5	100.0%	100.0%
Other	5	5	5	100.0%	100.0%
Totals	149	150	135		

Overall Classification Accuracy = 90.00%

Future Work

- Complete a landscape change analysis for areas where comparable earlier data sets exist;
- Complete a landscape analysis that describes the spatial arrangement of habitat cover types within the study area;
- Repeat this study in 2-5 years using similar imagery and consistent methods.

Data Availability

All spatial data are available from the Lower Columbia River Estuary Partnership, 811 SW Naito Pkwy, Suite 120, Portland, OR 97240 (*http://www.lcrep.org/*).

Acknowledgements

We gratefully acknowledge the support of the Lower Columbia River Estuary Partnership, Sea Resources, the Columbia River Estuary Task Force, the U.S. Army Corps of Engineers, U. S. Coast Guard, and the Bonneville Power Administration. We also thank Bruce Sutherland of the Estuary Partnership project manager, Jen Burke of NOAA Fisheries, George Dockray (our pilot), of ECOTRUST and the large group of volunteers coordinated by Jennie Boyd of the Estuary

Partnership who made this project possible. Finally, we would like to thank Crystal Elliot and Caren Crandel for their help in interpreting the volunteer plant community data.

Literature Cited

Allen, T. H. 1999. Areal distribution, change and restoration potential of wetlands within the lower Columbia River riparian zone, 1948-1991. Corvallis, OR, Oregon State University.

Garono, R. J., R. R. Robinson and C. A. Simenstad. 2003. Estuarine Landcover along the Lower Columbia River Estuary Determined from Landsat 7 ETM+ Imagery. Portland, OR, Lower Columbia River Estuary Partnership: 17.

Graves, J. K., J. A. Christy, P. J. Clinton and P. L. Britz. 1995. Historic habitats of the lower Columbia River. Astoria, OR, Columbia River Estuary Study Taskforce: 14.

Jerrick, N. 1999. The Lower Columbia River Estuary Program Comprehensive Conservation Management Plan: Volume 1. Portland, OR, The Lower Columbia River Estuary Program: 222.

NOAA. 1997. Columbia River Estuary Land Cover Change Project. Charleston, SC, NOAA Coastal Services Center.

Thomas, D. W. 1980. Study of the intertidal vegetation of the Columbia River Estuary. Astoria, OR, Columbia river Estuary Data Development Program.

Thomas, D. W. 1983. Changes in Columbia River Estuary Habitat Types over the Past Century. Astoria, OR, Columbia River Estuary Data Development Program, Columbia River Estuary Task Force: 50 pp.

FIGURES

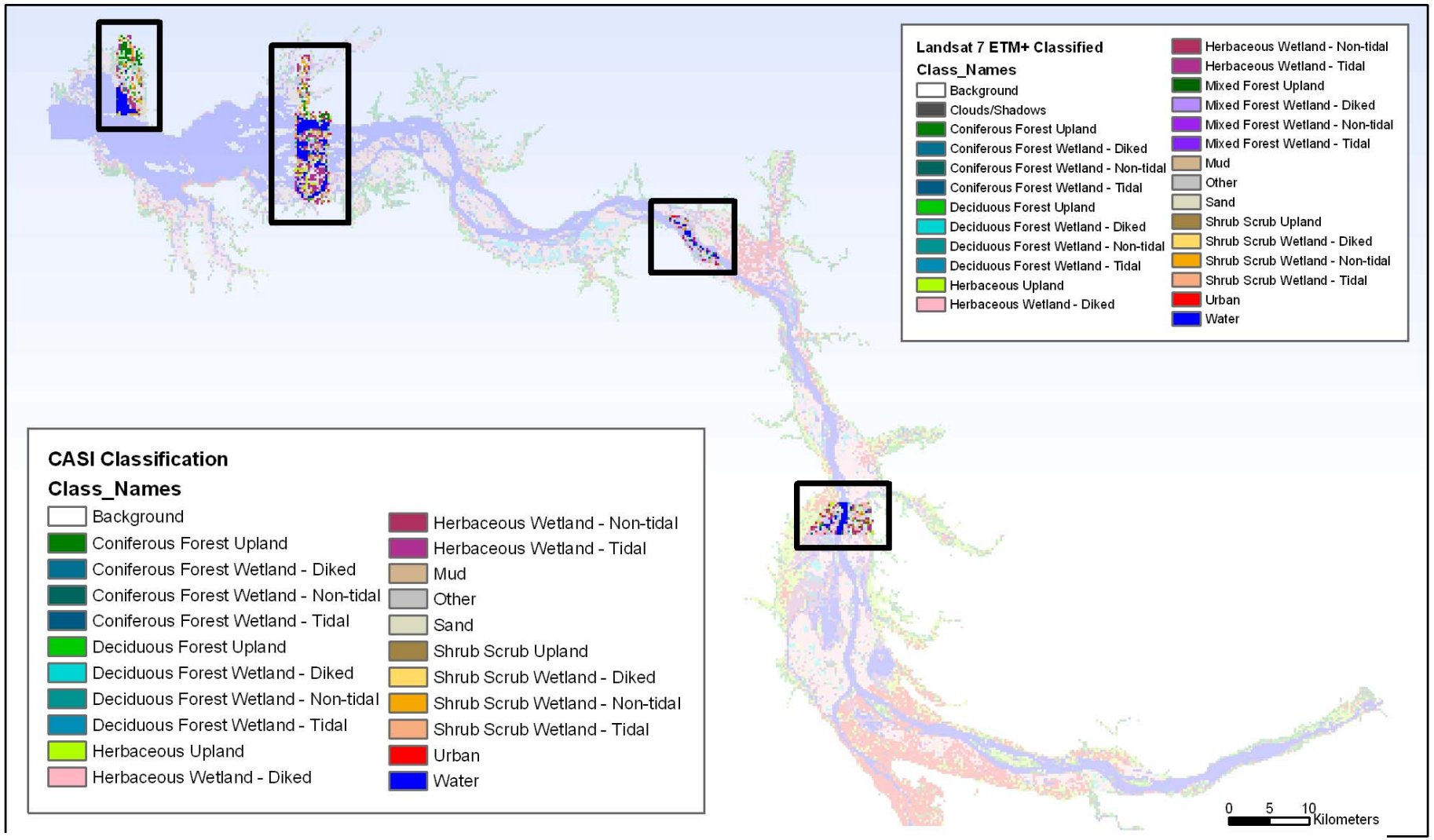

Figure 1. Lower Columbia River Estuary study area. Shown is the classified CASI imagery for the four focal areas, Chinook, Russian Island, Fisher-Lord Islands and Scappoose (from West to East), on a background derived from the classified Landsat 7 ETM+ imagery and the habitat cover classes for each classified image. TM imagery is deliberately faded to highlight CASI imagery.

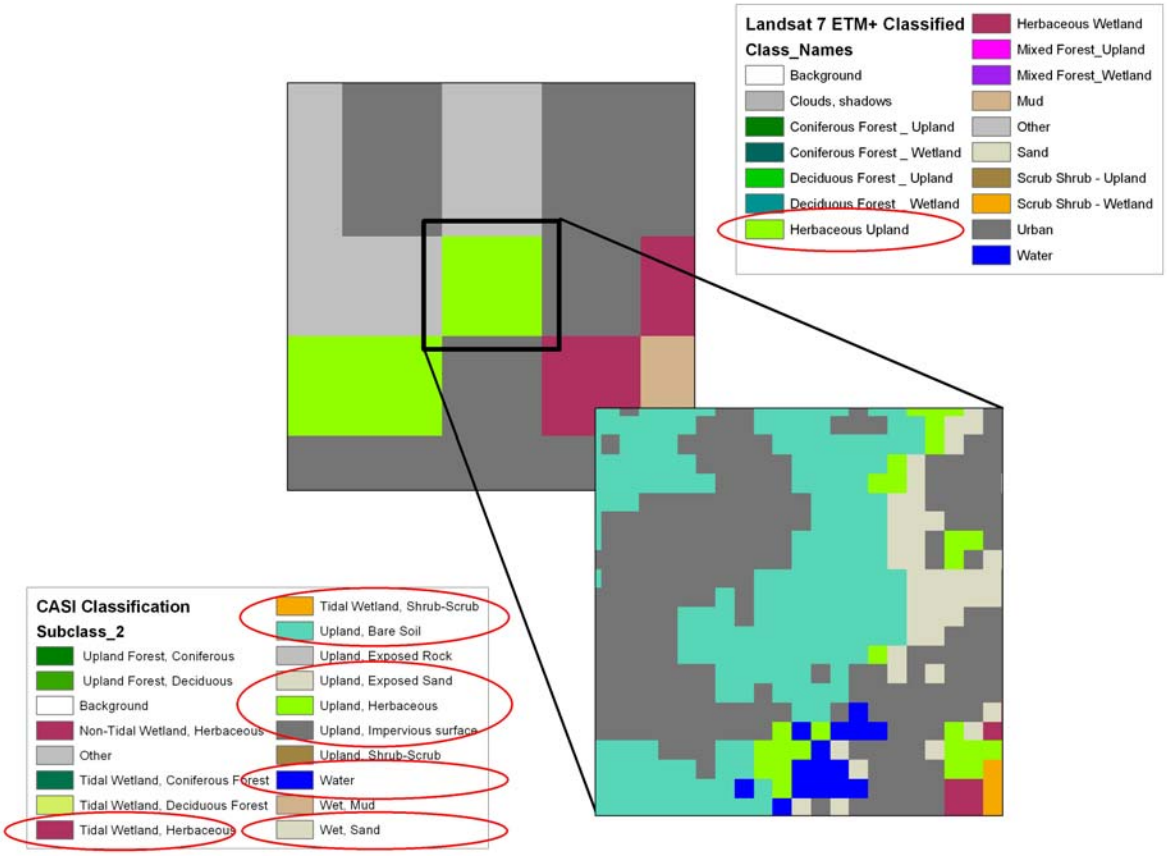

Figure 2. Illustration of the hierarchical nature of the data set produced from the classified Landsat 7 ETM+ and CASI imagery. Shown are example pixels from the Landsat 7 ETM+ image (30-m) on the top and the habitat cover classes from the CASI imagery (1.5-m) on the bottom. See also Appendix A.

Figure 3. Figure showing a ground control point (Target) and areas from which vegetation data were collected (Training Sites) by trained volunteers on an unclassified CASI image. Also shown is a cell from the grid used to collect plant community composition data (upper right).

Appendix A: Area (ha) of each cover class derived from classified CASI imagery for each of four focal areas on the Columbia River estuary. Shown are the Chinook, Russian Island, Fisher-Lord Islands, and Scappoose focal areas. Columns are cover class, subclass 1, subclass 2, subclass 3 and area: Cover class is the numeric value assigned to the grid cell in the image during classification; Subclass 1 indicates whether a grid cell is wetland, upland, water or other; Subclass 2 roughly equates to major cover classes shown in the classified Landsat 7 ETM+ classification; Subclass3 are the detailed cover classes derived from the CASI imagery for each focal area. Since all habitat cover classes did not appear in all focal areas and since accuracy assessments were not completed for these detailed cover classes, they should not be used to make comparisons between focal areas (except for the purple loosestrife cover classes no. 36 and 39).

Chinook

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
2	Upland	Urban	Buildings	10.4
3	Upland	Urban	Roads, Pavement	29.9
4	Upland	Sand	Bare Soil	13.2
7	Upland	Sand	Sand	0.0
8	Wetland	Mud	Mud	15.7
12	Wetland	Sand	Sand	8.3

Chinook

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
13	Wetland	Sand	Rock	0.8
14	Upland	Herbaceous Upland	Grass	68.4
15	Upland	Herbaceous Upland	Grass (Natural)	0.1
16	Upland	Herbaceous Upland	Grass (Lawn)	27.4
17	Upland	Herbaceous Upland	Grass (Pasture)	0.0
19	Wetland	Herbaceous Wetland Tidal	Unspecified	65.9
33	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Pacific Silverweed (POPA)	8.9
34	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Sidalcea sp. (SISP)	0.2
35	Wetland	Herbaceous Wetland Tidal	Rush mixed with Juncus/Holcus Corniculatus (JUEF/HOLA)	0.1
37	Wetland	Herbaceous Wetland Tidal	Grass: Phalaris	0.3
42	Wetland	Herbaceous Wetland Tidal	Grass: Holcus Lanatus (HOLA)	1.3
44	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Lotus Corniculatus (LOCO)	0.1
46	Wetland	Herbaceous Wetland Non-Tidal	Unspecified	120.7
50	Wetland	Herbaceous Wetland Diked	Grass (Agricultural)	11.2
51	Wetland	Herbaceous Wetland Diked	Grass (Pasture)	398.4
52	Wetland	Herbaceous Wetland Non-Tidal	Unspecified	0.3
53	Upland	Shrub-Scrub Upland	Unspecified	76.5
54	Upland	Shrub-Scrub Upland	Conifer	7.2
57	Upland	Shrub-Scrub Upland	Deciduous	16.9
60	Wetland	Shrub-Scrub Wetland Non-Tidal	Unspecified	50.0
61	Wetland	Shrub-Scrub Wetland Non-Tidal	Deciduous	4.4
62	Wetland	Shrub-Scrub Wetland Non-Tidal	Conifer	2.3
65	Upland	Coniferous Forest Upland	Conifer	649.7
68	Upland	Deciduous Forest Upland	Deciduous	146.8
76	Wetland	Deciduous Forest Wetland Non-Tidal	Deciduous	65.3
82	Wetland	Coniferous Forest Wetland	Conifer	165.3

Chinook

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
		Non-Tidal		
84	Water	Water	Water	584.5
85	Other	Other	Other - Targets	0.0
86	Other	Other	Other - Boats, Docks	1.2
87	Other	Other	Log Rafts, Pilings, Wood	3.0
94	Wetland	Herbaceous Wetland Diked	Unspecified	0.0
97	Wetland	Herbaceous Wetland Diked	Rush (Juncus)	0.9
106	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Pacific Silverweed (POPA)	6.3
107	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Sidalcea sp. (SISP)	0.2
108	Wetland	Herbaceous Wetland Diked	Rush mixed with Juncus/Holcus Corniculatus (JUEF/HOLA)	4.0
110	Wetland	Herbaceous Wetland Diked	Grass: Phalaris	29.8
115	Wetland	Herbaceous Wetland Diked	Grass: Holcus Lanatus (HOLA)	59.7
117	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Lotus Corniculatus (LOCO)	1.7
118	Wetland	Shrub-Scrub Wetland Diked	Unspecified	11.9
119	Wetland	Shrub-Scrub Wetland Diked	Deciduous	5.5
120	Wetland	Shrub-Scrub Wetland Diked	Conifer	0.8
123	Wetland	Deciduous Forest Wetland Diked	Deciduous	22.6
124	Wetland	Coniferous Forest Wetland Diked	Conifer	35.2
125	Wetland	Shrub-Scrub Wetland Tidal	Unspecified	5.0
126	Wetland	Shrub-Scrub Wetland Tidal	Deciduous	2.9
127	Wetland	Shrub-Scrub Wetland Tidal	Conifer	1.0
130	Wetland	Deciduous Forest Wetland Tidal	Deciduous	14.6
131	Wetland	Coniferous Forest Wetland Tidal	Conifer	45.8

Russian Island

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
2	Upland	Urban	Buildings	1.1
3	Upland	Urban	Roads, Pavement	4.8
4	Upland	Sand	Bare Soil	5.1
7	Upland	Sand	Sand	1.8
8	Wetland	Mud	Mud	767.3
9	Wetland	Mud	Mud/Green Algae	104.9
10	Wetland	Mud	Mud/Broad_Leaved	5.1
11	Wetland	Mud	Mud/Rush	7.4
12	Wetland	Sand	Sand	240.8
13	Wetland	Sand	Rock	0.1
14	Upland	Herbaceous Upland	Grass	87.2
17	Upland	Herbaceous Upland	Grass (Pasture)	0.0
19	Wetland	Herbaceous Wetland Tidal	Unspecified	430.1
20	Wetland	Herbaceous Wetland Tidal	Green Algae	1.8
22	Wetland	Herbaceous Wetland Tidal	Sedge, Dense	107.6
23	Wetland	Herbaceous Wetland Tidal	Sedge, Sparse	51.2
28	Wetland	Herbaceous Wetland Tidal	Rush (Eleocharis)	24.6
30	Wetland	Herbaceous Wetland Tidal	Rush (Lilaeopsis on Mud)	7.8
31	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Polygonium, Scirpus and Saggitaria	12.3
36	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Dense Purple Loosestrife	6.6
39	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Medium Purple Loosestrife	4.9
46	Wetland	Herbaceous Wetland Non-Tidal	Unspecified	13.0
50	Wetland	Herbaceous Wetland Diked	Grass (Agricultural)	6.9
51	Wetland	Herbaceous Wetland Diked	Grass (Pasture)	210.1
53	Upland	Shrub-Scrub Upland	Unspecified	20.5

Russian Island

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
54	Upland	Shrub-Scrub Upland	Conifer	7.4
55	Upland	Shrub-Scrub Upland	Deciduous (Oak)	0.0
57	Upland	Shrub-Scrub Upland	Deciduous	17.4
60	Wetland	Shrub-Scrub Wetland Non-Tidal	Unspecified	0.7
61	Wetland	Shrub-Scrub Wetland Non-Tidal	Deciduous	0.1
62	Wetland	Shrub-Scrub Wetland Non-Tidal	Conifer	0.3
65	Upland	Coniferous Forest Upland	Conifer	301.4
68	Upland	Deciduous Forest Upland	Deciduous	250.1
76	Wetland	Deciduous Forest Wetland Non-Tidal	Deciduous	5.8
82	Wetland	Coniferous Forest Wetland Non-Tidal	Conifer	7.6
84	Water	Water	Water	2,313.3
85	Other	Other	Other - Targets	0.0
86	Other	Other	Other - Boats, Docks	0.3
94	Wetland	Herbaceous Wetland Diked	Unspecified	5.5
95	Wetland	Herbaceous Wetland Diked	Sedge, Dense	24.1
96	Wetland	Herbaceous Wetland Diked	Sedge, Sparse	7.4
101	Wetland	Herbaceous Wetland Diked	Rush (Eleocharis)	4.2
103	Wetland	Herbaceous Wetland Diked	Rush (Lilaeopsis on Mud)	0.1
104	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Polygonium, Scirpus and Saggitaria	2.3
109	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Dense Purple Loosestrife	0.5
112	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Medium Purple Loosestrife	0.0
118	Wetland	Shrub-Scrub Wetland Diked	Unspecified	3.5
119	Wetland	Shrub-Scrub Wetland Diked	Deciduous	0.2

Russian Island

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
120	Wetland	Shrub-Scrub Wetland Diked	Conifer	0.6
123	Wetland	Deciduous Forest Wetland Diked	Deciduous	7.6
124	Wetland	Coniferous Forest Wetland Diked	Conifer	10.2
125	Wetland	Shrub-Scrub Wetland Tidal	Unspecified	9.6
126	Wetland	Shrub-Scrub Wetland Tidal	Deciduous	6.4
127	Wetland	Shrub-Scrub Wetland Tidal	Conifer	2.4
130	Wetland	Deciduous Forest Wetland Tidal	Deciduous	52.8
131	Wetland	Coniferous Forest Wetland Tidal	Conifer	79.2

Fisher-Lord Islands

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
4	Upland	Sand	Bare Soil	0.2
7	Upland	Sand	Sand	8.9
8	Wetland	Mud	Mud	2.0
9	Wetland	Mud	Mud/Green Algae	0.6
12	Wetland	Sand	Sand	16.6
14	Upland	Herbaceous Upland	Grass	39.1
19	Wetland	Herbaceous Wetland Tidal	Unspecified	57.8
22	Wetland	Herbaceous Wetland Tidal	Sedge, Dense	0.2

Fisher-Lord Islands

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
23	Wetland	Herbaceous Wetland Tidal	Sedge, Sparse	0.8
27	Wetland	Herbaceous Wetland Tidal	Sedge, Mixed with Bullrush, Phalaris	1.2
28	Wetland	Herbaceous Wetland Tidal	Rush (Eleocharis)	2.7
31	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Polygonium, Scirpus and Saggitaria	1.6
32	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Mixed includes Mytosis, Mentha, Convolvulus, Potentilla pacifica, Lathrus	9.8
35	Wetland	Herbaceous Wetland Tidal	Rush mixed with Juncus/Holcus Corniculatus (JUEF/HOLA)	0.6
37	Wetland	Herbaceous Wetland Tidal	Grass: Phalaris	8.1
38	Wetland	Herbaceous Wetland Tidal	Grass: Phalaris, Medium Purple Loosestrife, others	1.4
39	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Medium Purple Loosestrife	0.2
40	Wetland	Herbaceous Wetland Tidal	Grass: Rice Cutgrass	0.9
53	Upland	Shrub-Scrub Upland	Unspecified	4.2
57	Upland	Shrub-Scrub Upland	Deciduous	0.1
68	Upland	Deciduous Forest Upland	Deciduous	26.3
84	Water	Water	Water	571.8
87	Other	Other	Log Rafts, Pilings, Wood	0.1
89	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: BICE	0.2
125	Wetland	Shrub-Scrub Wetland Tidal	Unspecified	38.2
126	Wetland	Shrub-Scrub Wetland Tidal	Deciduous	2.3
130	Wetland	Deciduous Forest Wetland Tidal	Deciduous	199.0

Scappoose

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
2	Upland	Urban	Buildings	37.4
3	Upland	Urban	Roads, Pavement	82.2
4	Upland	Sand	Bare Soil	41.4
7	Upland	Sand	Sand	6.3
8	Wetland	Mud	Mud	22.1
12	Wetland	Sand	Sand	24.4
14	Upland	Herbaceous Upland	Grass	179.8
16	Upland	Herbaceous Upland	Grass (Lawn)	43.7
19	Wetland	Herbaceous Wetland Tidal	Unspecified	346.5
31	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Polygonium, Scirpus and Saggitaria	0.1
33	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Pacific Silverweed (POPA)	10.1
37	Wetland	Herbaceous Wetland Tidal	Grass: Phalaris	11.6
46	Wetland	Herbaceous Wetland Non-Tidal	Unspecified	6.8
49	Wetland	Herbaceous Wetland Diked	Grass (Natural)	0.0
50	Wetland	Herbaceous Wetland Diked	Grass (Agricultural)	63.2
51	Wetland	Herbaceous Wetland Diked	Grass (Pasture)	227.1
53	Upland	Shrub-Scrub Upland	Unspecified	73.2
60	Wetland	Shrub-Scrub Wetland Non-Tidal	Unspecified	2.6
65	Upland	Coniferous Forest Upland	Conifer	88.4
68	Upland	Deciduous Forest Upland	Deciduous	268.0
76	Wetland	Deciduous Forest Wetland Non-Tidal	Deciduous	5.1
82	Wetland	Coniferous Forest Wetland Non-Tidal	Conifer	1.3
84	Water	Water	Water	784.9
85	Other	Other	Other - Targets	0.0
86	Other	Other	Other - Boats, Docks	1.2
87	Other	Other	Log Rafts, Pilings, Wood	3.1
88	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: BICE/SALA	11.8
89	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: BICE	10.0
90	Wetland	Herbaceous Wetland Non-Tidal	Broad-Leaved: BICE/SALA	0.0

Scappoose

Cover Class	Subclass1	Subclass2	Subclass3	area (ha)
91	Wetland	Herbaceous Wetland Non-Tidal	Broad-Leaved: BICE	0.0
92	Wetland	Herbaceous Wetland Diked	Broad-Leaved: BICE/SALA	0.0
93	Wetland	Herbaceous Wetland Diked	Broad-Leaved: BICE	0.1
94	Wetland	Herbaceous Wetland Diked	Unspecified	0.1
106	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Pacific Silverweed (POPA)	0.7
110	Wetland	Herbaceous Wetland Diked	Grass: Phalaris	1.1
118	Wetland	Shrub-Scrub Wetland Diked	Unspecified	0.7
123	Wetland	Deciduous Forest Wetland Diked	Deciduous	6.1
124	Wetland	Coniferous Forest Wetland Diked	Conifer	1.3
125	Wetland	Shrub-Scrub Wetland Tidal	Unspecified	83.8
130	Wetland	Deciduous Forest Wetland Tidal	Deciduous	317.2
131	Wetland	Coniferous Forest Wetland Tidal	Conifer	51.1

Appendix B: Shown are the habitat cover class descriptions and the information used to derive each class. Cover class shows the value which occurs in the GIS GRID data layer. Sub_Class1 groups all cover classes into wetland, upland, other and water categories. Sub_Class2 groups cover classes into classes roughly equivalent to those used in the classification of the Landsat 7 ETM+ imagery (separate report). Sub_class3 are the detailed cover classes derived from the CASI imagery for each focal area. The 'Description' and 'Spectral vs. Ancillary Data Sources' provide summaries of the data sources used to derive each class and, in many cases, the composition of plant communities. Plant communities were sampled using 1.5 X 1.5-m grid cells (unless otherwise noted) and the percent cover of each species determined in the field and through analysis of photographs by University of Washington, Wetland Ecosystem Team personnel (see text for details). **Since <u>all</u> habitat cover classes did not appear in <u>all</u> focal areas, and since accuracy assessments were not completed for these detailed cover classes, they should <u>not</u> be used to make comparisons between focal areas (except for the purple loosestrife cover classes no. 36 and 39).**

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
2	Upland	Urban	Buildings	Urban areas were identified from the unclassified CASI imagery and ancillary photography. The urban cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	ancillary - digitized AOIs
3	Upland	Urban	Roads, Pavement	Roads and pavement were identified from the unclassified CASI imagery and ancillary photography. The roads and pavement cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	ancillary - digitized AOIs
4	Upland	Sand	Bare Soil	Training site spectra were taken from areas identified as bare soil from the unclassified CASI imagery and ancillary photography. These spectral signatures were used in image processing. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	spectral
7	Upland	Sand	Sand	Training site spectra were taken from areas identified as bare sand from the unclassified CASI imagery and ancillary photography. These spectral signatures were used in image processing. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	spectral
8	Wetland	Mud	Mud	Training site spectra were taken from areas identified as bare mud from the unclassified CASI imagery and ancillary photography. These spectral signatures were used in image processing. These sites fell within areas identified	spectral

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
				as 'Wetland' using the Wetland-Upland mask.	
9	Wetland	Mud	Mud/Green Algae	Training site spectra were taken from areas identified as mud and green algae (cover ranging from 29%-40%) from field training sites. These spectral signatures were used in image processing. These sites fell within areas identified as 'Wetland' using the Wetland-Upland mask.	spectral
10	Wetland	Mud	Mud/Broad_Leaved	Training site spectra were taken from areas identified as mud and Callitriche (cover ~31%) from field training sites. These spectral signatures were used in image processing. These sites fell within areas identified as 'Wetland' using the Wetland-Upland mask.	spectral
11	Wetland	Mud	Mud/Rush	Training site spectra were taken from areas identified as mud and Eleocharis spp. (cover ~40%) from field training sites. These spectral signatures were used in image processing. These sites fell within areas identified as 'Wetland' using the Wetland-Upland mask.	spectral
12	Wetland	Sand	Sand	Sand was identified from the unclassified CASI imagery and ancillary photography. These spectral signatures were used in image processing. These sites fell within areas identified as 'Wetland' using the Wetland-Upland mask.	spectral

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
13	Wetland	Sand	Rock	Rock was identified from the unclassified CASI imagery and ancillary photography. These spectral signatures were used in image processing. These sites fell within areas identified as 'Wetland' using the Wetland-Upland mask.	spectral
14	Upland	Herbaceous Upland	Grass	Training site spectra were taken from areas identified as Upland Herbaceous (dominant species, Agrostis alba cover ranged from 7%-8%; Bromus tectorum cover ranged from 12%-29%; and Moss and Lichen cover ranged from 29%-42%) from field training sites. These spectral signatures were used in image processing. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	spectral
15	Upland	Herbaceous Upland	Grass (Natural)	Upland Herbaceous (Natural) areas were identified from the unclassified CASI imagery and ancillary photography. These areas were identified as not being lawns or pastures. These spectral signatures were used in image processing. These spectral signatures were used in image processing. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	spectral

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
16	Upland	Herbaceous Upland	Grass (Lawn)	Upland Herbaceous (Lawn) areas were identified from the unclassified CASI imagery and ancillary photography. These areas were generally in urban areas. The Upland Herbaceous (Lawn) cover class was manually assigned to these areas. These spectral signatures were used in image processing. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	spectral
17	Upland	Herbaceous Upland	Grass (Pasture)	Upland Herbaceous (Pasture) areas were identified from the unclassified CASI imagery and ancillary photography. These areas were identified as pastures by shape, texture or the presence of livestock. These spectral signatures were used in image processing. These spectral signatures were used in image processing. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask.	spectral
19	Wetland	Herbaceous Tidal Wetland	Unspecified	Training site spectra were taken from areas identified as Herbaceous Wetland from all data sources. This cover class was used when herbaceous wetland classes could not be further distinguished from spectral data. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
20	Wetland	Herbaceous Wetland Tidal	Green Algae	Training site spectra were taken from areas identified as Herbaceous Wetland (cover was 59% green algae and 40% sand) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
22	Wetland	Herbaceous Wetland Tidal	Sedge, Dense	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 35%-99% Carex lyngbyei) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
23	Wetland	Herbaceous Wetland Tidal	Sedge, Sparse	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 16%-40% Carex lyngbyei; also included Potentilla pacifica (1%-15%), Mentha spp. (1%-16%), and Phalaris arundinacea (0%-11%)) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
27	Wetland	Herbaceous Wetland Tidal	Sedge, Mixed with Bullrush, Phalaris	Training site spectra were taken from areas identified as Herbaceous Wetland (Sedge, Mixed with Bullrush and Phalaris) from the unclassified CASI imagery, ancillary photography and qualitative field observations. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
				image processing.	
28	Wetland	Herbaceous Tidal	Wetland Rush (Eleocharis)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 9%-98% Eleocharis palustris; one training site with low Eleocharis cover was otherwise bare) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
30	Wetland	Herbaceous Tidal	Wetland Rush (Lilaeopsis on Mud)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 42%-48% Lilaeopsis occidentalis and 11%-13% green algae on mud) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
31	Wetland	Herbaceous Tidal	Wetland Broad-Leaved: Polygonium, Scirpus and Saggitaria	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 25%-91% Polygonum lapathifolium; also Gnaphalium uliginosum (0-52%), and Sparganium sp. (1%-14%), and areas of Scirpus americanus, and Sagittaria latifolia) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
				were used in image processing.	
32	Wetland	Herbaceous Tidal	Wetland Broad-Leaved: Mixed includes Mytosis, Mentha, Convolvulus, Potentilla pacifica, Lathrus	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 3%-63% Bidens cernua and 0%-40% Eleocharis Palustris on sand/mud (0%-25%)) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
33	Wetland	Herbaceous Tidal	Wetland Broad-Leaved: Mixed includes Pacific Silverweed, Bidens, Saggittaria and Phalaris	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 0%-87% Potentilla pacifica, Bidens cernua (15%-72%), Sagittaria latifolia (3%-30%), Juncus effusus (0%-22%), and Phalaris arundinacea (0%-12%)) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
34	Wetland	Herbaceous Tidal	Wetland Broad-Leaved: Sidalcea sp. (SISP)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover was 81% Sidalcea sp. and 13% Potentilla pacifica) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
				spectral signatures were used in image processing.	
35	Wetland	Herbaceous Tidal	Wetland Rush mixed with Juncus/Holcus Corniculatus (JUEF/HOLA)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 24%-26% Lotus corniculatus, Agrostis alba (16%-17%), Juncus effusus (0%-26%, Holcus corniculatus (0%-30%)) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
36	Wetland	Herbaceous Tidal	Wetland Broad-Leaved: Dense Purple Loosestrife	Training site spectra were taken from areas identified as dense purple loosestrife sampled with quadrats generally accounting for 60%-100% of the cover. We also used the unclassified CASI imagery, ancillary photography and field sampled GPS locations in deriving this cover class. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
37	Wetland	Herbaceous Tidal	Wetland Grass: Phalaris	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 78%-95% Phalaris arundinacea) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
38	Wetland	Herbaceous Wetland Tidal	Grass: Phalaris, Medium Purple Loosestrife, others	Training site spectra were taken from areas identified as medium density purple loosestrife and Phalaris arundinacea sampled with quadrats each species generally accounting for 15% to 50% of the cover. We also used the unclassified CASI imagery, ancillary photography and field sampled GPS locations in deriving this cover class. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
39	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: Medium Purple Loosestrife	Training site spectra were taken from areas identified as medium density purple loosestrife sampled with quadrats generally accounting for 30% to 50% of the cover. We also used the unclassified CASI imagery, ancillary photography and field sampled GPS locations in deriving this cover class. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
40	Wetland	Herbaceous Wetland Tidal	Grass: Rice Cutgrass	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 60%-100% Leersia oryzoides) from field sites that were GPSed. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
42	Wetland	Herbaceous Tidal	Grass: Holcus Lanatus (HOLA)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 60%-89% Holcus lanatus and Agrostis alba (6%-23%) from field training sites. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
44	Wetland	Herbaceous Tidal	Broad-Leaved: Lotus Corniculatus (LOCO)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 30%-60% Lotus corniculatus) from field sites that were GPSed. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
46	Wetland	Herbaceous Non-Tidal	Upspecified	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by unknown herbaceous vegetation at field sites that were GPSed. These sites fell within areas identified as 'Non-Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
49	Wetland	Herbaceous Diked	Grass (Natural)	Upland Herbaceous (Natural) areas were identified from the unclassified CASI imagery and ancillary photography. These areas were identified as not being lawns or pastures. These spectral signatures were used in image processing. These spectral signatures were used in image processing. These sites fell within areas identified as 'Diked' using the dike and tidal mask.	spectral/ancillary - NWI, DEM, Dike Map

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
50	Wetland	Herbaceous Diked Wetland	Grass (Agricultural)	Wetland Herbaceous (Agricultural) areas were identified from the unclassified CASI imagery and ancillary photography. These sites fell within areas identified as 'Diked' using the Dike and tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
51	Wetland	Herbaceous Diked Wetland	Grass (Pasture)	Wetland Herbaceous (Pasture) areas were identified from the unclassified CASI imagery and ancillary photography. These sites fell within areas identified as 'Diked' using the Dike and tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
52	Wetland	Herbaceous Non-Tidal Wetland	Unspecified	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by unknown herbaceous vegetation at field sites that were GPSed. These sites fell within areas identified as 'Non-Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
53	Upland	Shrub-Scrub Upland	Unspecified	Upland Shrub-Scrub (Unspecified) areas were identified from the unclassified CASI imagery and ancillary photography. The Upland Shrub-Scrub (Unspecified) cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
54	Upland	Shrub-Scrub Upland	Conifer	Upland Shrub-Scrub (Conifer) areas were identified from the unclassified CASI imagery and ancillary photography. The Upland Shrub-Scrub (Conifer) cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask	spectral/ancillary - NWI, DEM
55	Upland	Shrub-Scrub Upland	Deciduous (Oak)	Shrub-Scrub (Deciduous:Oak) areas were identified from the unclassified CASI imagery and ancillary photography. The Shrub-Scrub (Deciduous:Oak) cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask	spectral/ancillary - NWI, DEM
57	Upland	Shrub-Scrub Upland	Deciduous	Upland Shrub-Scrub (Deciduous) areas were identified from the unclassified CASI imagery and ancillary photography. The Upland Shrub-Scrub (Deciduous) cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask	spectral/ancillary - NWI, DEM
60	Wetland	Shrub-Scrub Wetland Non-Tidal	Unspecified	Wetland Shrub-Scrub (Unspecified) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Unspecified) cover class was manually assigned to these areas. These sites fell within areas identified as 'Non-Tidal' using the tidal mask	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
61	Wetland	Shrub-Scrub Non-Tidal	Wetland Deciduous	Wetland Shrub-Scrub (Deciduous) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Deciduous) cover class was manually assigned to these areas. These sites fell within areas identified as 'Non-Tidal' using the tidal mask	spectral/ancillary - NWI, DEM
62	Wetland	Shrub-Scrub Non-Tidal	Wetland Conifer	Wetland Shrub-Scrub (Conifer) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Conifer) cover class was manually assigned to these areas. These sites fell within areas identified as 'Non-Tidal' using the tidal mask	spectral/ancillary - NWI, DEM
65	Upland, Coniferous Forest	Upland, Forest	Coniferous Conifer	Upland Coniferous Forest areas were identified from the unclassified CASI imagery and ancillary photography. The Upland Coniferous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask	spectral/ancillary - NWI, DEM
68	Upland, Deciduous Forest	Upland, Forest	Deciduous Deciduous	Upland Deciduous Forest areas were identified from the unclassified CASI imagery and ancillary photography. The Upland Deciduous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Upland' using the Wetland-Upland mask	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
76	Wetland	Deciduous Forest Wetland Non-Tidal	Deciduous	Wetland Deciduous Forest (Non-Tidal) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Deciduous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Non-Tidal' using the tidal mask	spectral/ancillary - NWI, DEM
82	Wetland	Coniferous Forest Wetland Non-Tidal	Conifer	Wetland Coniferous Forest (Non-Tidal) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Coniferous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Non-Tidal' using the tidal mask	spectral/ancillary - NWI, DEM
84	Water	Water	Water	Water areas were identified from the unclassified CASI imagery and ancillary photography. The Water cover class was manually assigned to these areas.	spectral
85	Other	Other	Other - Targets	Other (Targets) areas were identified from the unclassified CASI imagery and ancillary photography. Targets were placed at marsh sites by our field teams. The Other (Targets) cover class was manually assigned to these areas.	spectral/ancillary - AOIs
86	Other	Other	Other - Boats, Docks	Other (Boats, Docks) areas were identified from the unclassified CASI imagery and ancillary photography. The Other (Boats, Docks) cover class was manually assigned to these areas.	spectral/ancillary - AOIs

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
87	Other	Other	Log Rafts, Pilings, Wood	Other (Log Rafts, Pilings, Wood) areas were identified from the unclassified CASI imagery and ancillary photography. The Other (Boats, Docks) cover class was manually assigned to these areas.	spectral/ancillary - AOIs
88	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: BICE/SALA	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by Bidense cernua and Sagittaria latifolia determined from field sites that were GPSed. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
89	Wetland	Herbaceous Wetland Tidal	Broad-Leaved: BICE	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by Bidens cernua at field sites that were GPSed. These sites fell within areas identified as 'Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
90	Wetland	Herbaceous Wetland Non-Tidal	Broad-Leaved: BICE/SALA	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by Bidense cernua and Sagittaria latifolia determined from field sites that were GPSed. These sites fell within areas identified as 'Non-Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
91	Wetland	Herbaceous Non-Tidal Wetland	Broad-Leaved: BICE	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by Bidens cernua at field sites that were GPSed. These sites fell within areas identified as 'Non-Tidal' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
92	Wetland	Herbaceous Diked Wetland	Broad-Leaved: BICE/SALA	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by Bidense cernua and Sagittaria latifolia determined from field sites that were GPSed. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
93	Wetland	Herbaceous Diked Wetland	Broad-Leaved: BICE	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by Bidens cernua at field sites that were GPSed. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
94	Wetland	Herbaceous Diked Wetland	Unspecified	Training site spectra were taken from areas identified as Herbaceous Wetland dominated by unknown herbaceous vegetation at field sites that were GPSed. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
95	Wetland	Herbaceous Wetland Diked	Sedge, Dense	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 35%-99% Carex lyngbyei) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
96	Wetland	Herbaceous Wetland Diked	Sedge, Sparse	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 16%-40% Carex lyngbyei; also included Potentilla pacifica (1%-15%), Mentha spp. (1%-16%), and Phalaris arundinacea (0%-11%)) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
97	Wetland	Herbaceous Wetland Diked	Rush (Juncus)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 74%-100% Juncus spp.) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
101	Wetland	Herbaceous Wetland Diked	Rush (Eleocharis)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 9%-98% Eleocharis palustris; one training site with low Eleocharis cover was otherwise bare) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image	spectral/ancillary - NWI, DEM, Dike Map

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
				processing.	
103	Wetland	Herbaceous Wetland Diked	Rush (Lilaeopsis on Mud)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 42%-48% Lilaeopsis occidentalis and 11%-13% green algae on mud) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
104	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Polygonium, Scirpus and Saggitaria	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 25%-91% Polygonum lapathifolium; also Gnaphalium uliginosum (0-52%), and Sparganium sp. (1%-14%), and areas of Scirpus americanus, and Sagittaria latifolia) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
106	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Mixed includes Pacific Silverweed, Bidens, Saggittaria and Phalaris	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 0%-87% Potentilla pacifica, Bidens cernua (15%-72%), Sagittaria latifolia (3%-30%), Juncus effusus (0%-22%), and Phalaris arundinacea (0%-12%)) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask.	spectral/ancillary - NWI, DEM, Dike Map

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
				These spectral signatures were used in image processing.	
107	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Sidalcea sp. (SISP)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover was 81% Sidalcea sp. and 13% Potentilla pacifica) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
108	Wetland	Herbaceous Wetland Diked	Rush mixed with Juncus/Holcus Corniculatus (JUEF/HOLA)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 24%-26% Lotus corniculatus, Agrostis alba (16%-17%), Juncus effusus (0%-26%, Holcus corniculatus (0%-30%)) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
109	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Dense Purple Loosestrife	Training site spectra were taken from areas identified as dense purple loosestrife sampled with quadrats generally accounting for 60%-100% of the cover. We also used the unclassified CASI imagery, ancillary photography and field sampled GPS locations in deriving this cover class. These sites fell within areas identified as 'Diked'	spectral/ancillary - NWI, DEM, Dike Map

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
				using the tidal mask. These spectral signatures were used in image processing.	
110	Wetland	Herbaceous Wetland Diked	Grass: Phalaris	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 78%-95% Phalaris arundinacea) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
112	Wetland	Herbaceous Wetland Diked	Broad-Leaved: Medium Purple Loosestrife	Training site spectra were taken from areas identified as medium density purple loosestrife sampled with quadrats generally accounting for 30% to 50% of the cover. We also used the unclassified CASI imagery, ancillary photography and field sampled GPS locations in deriving this cover class. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map
115	Wetland	Herbaceous Wetland Diked	Grass: Holcus Lanatus (HOLA)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 60%-89% Holcus lanatus and Agrostis alba (6%-23%) from field training sites. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM, Dike Map

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
117	Wetland	Herbaceous Diked Wetland	Broad-Leaved: Lotus Corniculatus (LOCO)	Training site spectra were taken from areas identified as Herbaceous Wetland (cover ranged from 30%-60% Lotus corniculatus) from field sites that were GPSed. These sites fell within areas identified as 'Diked' using the tidal mask. These spectral signatures were used in image processing.	spectral/ancillary - NWI, DEM
118	Wetland	Shrub-Scrub Diked Wetland	Unspecified	Wetland Shrub-Scrub (Unspecified) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Unspecified) cover class was manually assigned to these areas. These sites fell within areas identified as 'Diked' using the tidal mask	spectral/ancillary - NWI, DEM
119	Wetland	Shrub-Scrub Diked Wetland	Deciduous	Wetland Shrub-Scrub (Deciduous) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Deciduous) cover class was manually assigned to these areas. These sites fell within areas identified as 'Diked' using the tidal mask	spectral/ancillary - NWI, DEM
120	Wetland	Shrub-Scrub Diked Wetland	Conifer	Wetland Shrub-Scrub (Conifer) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Conifer) cover class was manually assigned to these areas. These sites fell within areas identified as 'Diked' using the tidal mask	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
123	Wetland	Deciduous Forest Wetland Diked	Deciduous	Wetland Deciduous Forest (Diked) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Deciduous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Diked' using the tidal mask	spectral/ancillary - NWI, DEM
124	Wetland	Coniferous Forest Wetland Diked	Conifer	Wetland Coniferous Forest (Diked) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Coniferous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Diked' using the tidal mask	spectral/ancillary - NWI, DEM
125	Wetland	Shrub-Scrub Wetland Tidal	Unspecified	Wetland Shrub-Scrub (Unspecified) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Unspecified) cover class was manually assigned to these areas. These sites fell within areas identified as 'Tidal' using the tidal mask	spectral/ancillary - NWI, DEM
126	Wetland	Shrub-Scrub Wetland Tidal	Deciduous	Wetland Shrub-Scrub (Deciduous) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Deciduous) cover class was manually assigned to these areas. These sites fell within areas identified as 'Tidal' using the tidal mask	spectral/ancillary - NWI, DEM

Cover Class	Sub_Class1	Sub_Class2	Sub_Class3	Description of Cover Class	Spectral vs ancillary Data Sources
127	Wetland	Shrub-Scrub Wetland Tidal	Conifer	Wetland Shrub-Scrub (Conifer) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Shrub-Scrub (Conifer) cover class was manually assigned to these areas. These sites fell within areas identified as 'Tidal' using the tidal mask.	spectral/ancillary - NWI, DEM
130	Wetland	Deciduous Forest Wetland Tidal	Deciduous	Wetland Deciduous Forest (Tidal) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Deciduous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Tidal' using the tidal mask	spectral/ancillary - NWI, DEM
131	Wetland	Coniferous Forest Wetland Tidal	Conifer	Wetland Coniferous Forest (Tidal) areas were identified from the unclassified CASI imagery and ancillary photography. The Wetland Coniferous Forest cover class was manually assigned to these areas. These sites fell within areas identified as 'Tidal' using the tidal mask	spectral/ancillary - NWI, DEM